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Interactive Terrain Surface Visualization using Haptics Assisted Display

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Abstract—In this paper we present a novel method to handle terrain surface features using haptic feedback providing interaction for the purpose of navigation of terrain over a virtual 3D environment. This system uses Phantom Haptics Desktop Device for touch bound interactions using force feedback stylus, which acts as a pointer that allows the user to feel the deformations over the terrain surface. The advantage of haptic feedback is that it works in 3D environment and provides better control with the force compared to mouse and other hardware.

Index Terms—Haptics Visualization, Navigation, Terrain classification.

I. INTRODUCTION

In scientific and space applications, visualization is most important for experimentation and research. Haptics visualization of terrain surfaces for navigation of rover activities is very rare. The previous have been dealt with haptic visualization and activities related to Medical applications and activities related to volumetric and point data sets. Applications were more towards handling of Geographical Information System(GIS) data editing and visualization. The haptic visualization methods can also be used in analysing the terrain surface for navigation with a sense of touch by the user in addition to visual graphics. Moreover, haptic devices provide interactions in the 3D environment. Our experiment uses Phantom Desktop Device with Chai3D haptic library.

Various approaches to exploration, visualization, and intuitive editing of GIS data have been developed last years, but there are still many open problems. One of them is the haptic visualization and editing of terrains. The haptic visualization has the potential to provide additional information to the user (sense of touch) in addition to visual output only. And, unlike the mouse or keyboard, the haptic devices provide native 3D manipulation, which is also more intuitive. Haptic devices were very expensive but, nowadays, they are becoming affordable for general public. The most commonly used terrain representation in existing haptic applications is digital elevation model (DEM) based on a regular grid or volume data. Volumetric-based or grid-based methods are memory consuming, because the resolution of the grid must correspond to the smallest detail of the model. To the best of our knowledge, there is no suitable haptic method which works natively with TIN and allows both editing and simulation of physical processes on the terrain.

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We have developed a haptic visualization method which works natively with TIN and allows interactive editing of the terrain simulation using a haptic device. User can form a cursor shape into the terrain to drag it across the terrain. The physical model of the terrain has plane and rough surfaces with peaks and depths but our approach is general enough to simulate any kind of surfaces.

The goal of our haptic visualization is to be realistic, easy to use, and reasonably fast to be usable. Our method uses the triangulation framework based representation. We have examples of creating various editing tool shapes, such as rectangle, circle, sphere, ellipsoid, and man foot print. As the haptic device provides point-based feedback, all forces exerted on our shapes must be mapped to a single point.

II. RELATED WORK

The paper presented refers to haptic visualization [5] for classifying terrain and identifying path for navigating rover over terrain surface. This is related to scientific visualization, human computer interaction interface and exploration in a 3D virtual world.

Earlier work investigating path visualization for navigation was presented in [14]. This realizes the physically simulated navigation with haptic controller with animated avatar in a virtual environment. Jorissen et al, [14] presented work on force feedback interaction over a terrain surface. Interactive editing is explained for large terrain data [3], gives us an idea of how Haptics interface is used in sand manipulation of Virtual Environment but it lacks other soft or hard surface interaction.

Experiments of Faeth et al., depict scientific geo-visualization in 3D immersive environments of virtual reality [5]. Our work also emphasizes interactive visualization with haptic assisted display.

Virtual-reality interfaces offer several advantages for scientific visualization. Direct manipulation allows the intuitive exploration of those graphics data (or subset), which facilitates the discovery of data features that would be difficult to find using more conventional visualization methods. In order to implement an effective multimodal scientific visualization application in a virtual environment, issues of responsiveness and fast updates must be addressed. Haptic feedback is a promising interaction modality for a variety of applications, mainly to increase the realism of simulation and to improve operator performance. In contrast to visual displays, haptic interfaces create a tightly coupled information flow via force feedback method. A majority of the earlier methods for haptic displays of volume data properties are based on a fundamental relationship between the haptic probe position/velocity and the data at that point.

Haptic stability is an issue in constrained haptic interaction where the haptic probe makes a rigid contact with the surfaces. Visualization of visibility information is critical for many mission planning applications, terrain assessment and in path classification. We have identified this problem and designed a method of visualization for rover navigation environment that allows the user to interactively explore the terrain visibility. Our novel method of visualization is based on a metric for measuring visibility over space that is stored as scalar field. The scalar field is visualized using standard volume visualization techniques. We have proposed the idea of using Force to haptically explore the visibility data, and also to optimize navigational paths. The interaction scheme that we have used helps the user in several ways.

III. Methods

3.1. Terrain Data Modelling:

This setup is classified as the geometric model, physics simulation, and haptic interaction. The input to our system is a set of 3D points [x, y, z], where x and y defines the position in terrain and z is an elevation of the terrain. The points are given by a height map, by an image, or a function. The output of this process is the triangulation framework of the given set of points, which we use for physics simulation. Triangulation framework is formed using the incremental insertion algorithm. This algorithm is very useful for our purpose, because it can add vertices into the triangulation on the fly. So the terrain modification could be easily handled. Terrain could be modified by erosion or by haptic device. We use a set of virtual tools for the haptic manipulation. The tool consists of a set of control points and edges between these points. The terrain is deformed inside the virtual tool shape according to this shape and according to the user requirements. The height of these points adapts to the terrain height in the current tool position when the tool is imprinted into the terrain, (Figure 1). The amount of material pushed away by the tool is defined as a difference between heights of the tool depth level, and height of the control points in the direction of tool movement.

3.2. Haptics Visualization:

The vibrotactile actuators from device are used to render information about the terrain type such as sands, rocks, plane surface, and slope. This information is rendered as high frequency vibration simulating surface textures. In this way the user can experience the tactile feeling of the different terrain types and conditions even if it is a plane surface of non uniformed textures. We also rendered the lunar terrain map taken from DEM data as a 3D image gives the user the depth perception. Placing the haptic stylus over the image of terrain and moving it over, the surface is rendered accordingly based on the interaction. Proper texture signal is sent to the user when the user in contact with the terrain via stylus. The surface is represented using the haptic effects. There are three regions we identified using haptics interaction. A bump surface, a frictional surface and surface on gravity lines. The bump surface using haptics is mainly to find the elevation over the terrain. The user will identify the bump by taking the gray scale image of the elevation and displaces the height of pixel up or down based on elevation. Frictional surface through haptics is done by identifying the surfaces by rough, semi rough and smooth. Three kinds of regions also can be known by using the gray scale images in which white area indicate lowest friction region, gray areas indicate semi rough region and black areas indicate rough region. The haptics device that we used is a PHANTOM Desktop as shown in figure. It offers 6 degrees of freedom (DOF) in the input whereas 3 DOF is available for the force feedback. We can have bidirectional communication for interaction. All displacements (mainly position and rotation) of the device are respectively mapped to the position and rotation of the terrain. The force feedback is computed via a spring model that simulates the non penetration of the 3D terrain, as indicated below.

$$F=k*X \quad \text{--} \quad (1)$$

In this, k defines the stiffness coefficient of the spring while X is the penetration of the virtual terrain. With this model, the more the user penetrates the virtual surface, greater the force feedback is. This will allow the user to perceive the elevation of the terrain. This will also make the user to feel the shape of the visually rendered terrain surface in greater detail.

3.3 Force Computation:

The force feedback F consists of two forces. The first one is a penetration force Fp and it depends on the tool depth level – a deeper penetration results in a larger force which acts strictly in the vertical direction for surface and our set of tools. It is impossible to feel the difference between our simplified strictly vertical Fp and the real, physically correct Fp.

The second part of the force feedback is the friction force Fr, which is physically defined by Equation 2. It depends also on the penetration depth in the direction of tool movement and on the speed of tool movement – a higher velocity means a larger force which acts against the tool movement direction.

$$Fr=u.Fn, \quad \text{------------------------------------}(2)$$

Where u is the coefficient of friction, which is empirical property which differs for each material, and Fn is the normal force which is perpendicular to the surface and acts against the tool. In our method we use an approximation of this physical law.

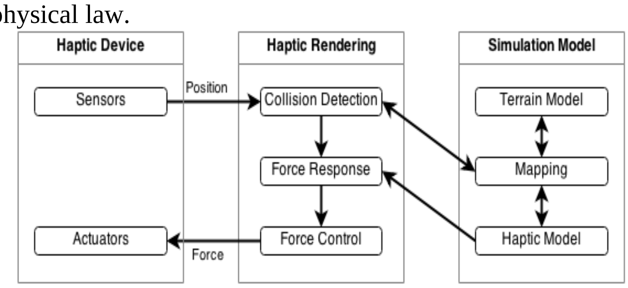

Fig 1. Block Diagram of Haptics Rendering with terrain visualization model

IV. Implementation and Results

The visualization system is implemented in C++ with OpenGL graphics library and the Chai 3D open source haptic rendering library for interfacing with Phantom Haptic Device. Chai 3D library will support Phantom devices and is more user friendly and easy to test with Virtual Haptic Device which comes along with the Chai 3D library.

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The example source code provided with this Chai3D library will give an additional advantage to easily interface it to other haptics devices.

The Terrain visualization application contains of two major modules: the graphics module and the haptic rendering module. Both modules are interfaced to help user to interact with virtual terrain with haptics feedback.

In each haptic rendering loop, we read the actual position of the haptic device in 3D space. We transform it as a position of the virtual point of device and we compute the responding forces over the terrain surface. The update rates of these two loops are very different since a visual rendering needs a much slower refresh rate compared to a haptic update rate. While a 60Hz refresh rate is standard for visual rendering, the haptic rendering requires at least a 1kHz update rate to provide smooth haptic feedback to a human user. In our application, we use a high frequency timer for the haptic feedback so that the haptic rendering loop takes place in every millisecond. The commands in the haptic loop are not buffered. Once entered the callback application does not execute the same routine until it is terminated. If there is some piece of code that takes a long time, the newly generated position can be much farther. The haptic loop is no re-entrant. It is important to keep all the complicated calculations out of the haptic loop and use it just for setting some variables. Actually, synchronization of the visual and the haptic loops presents an interesting problem in general.

The system runs on a HP Z400 workstation with Intel Xeon CPU running at 3.2GHz with the NVIDIA Quadro 2000 graphics card. The haptic feedback does provide a higher level of fidelity than using only visual feedback. We have demonstrated that implementation of interactive sand sculpting system with haptic feedback is possible and leads to better results than just visual feedback. We have shown that applications of our approach could be as a plug-in for packages like 3D Studio MAX. It is a challenging to model complex scenes by simple haptic feedback and the user could then test animation sequences using this method. It is found that the haptic feedback is incomparably better than just a visual feedback as we tested when just using a mouse instead of the Phantom Desktop device.

V. REAL TERRAIN IMAGES AND RESULTS

We have performed experiments on terrain images obtained from LRO data and other interplanetary terrain data. The terrain available as DEM is sampled at 256 X 256 resolution.

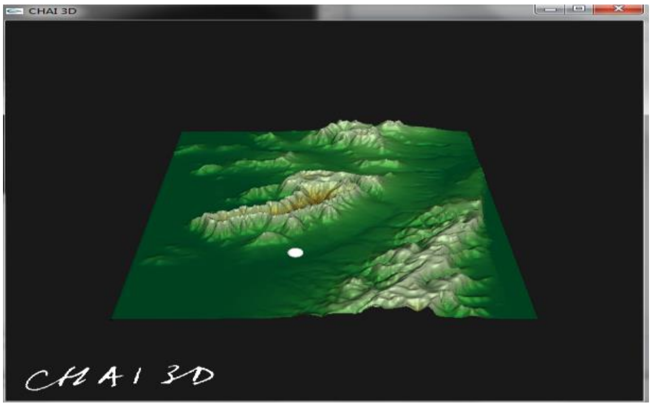

Fig 2 Real terrain in a virtual visualization media with haptics pointer

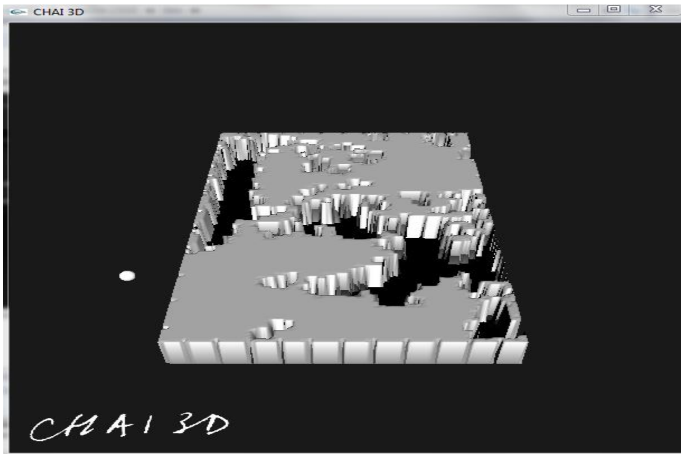

Fig.3 The terrain in 3D

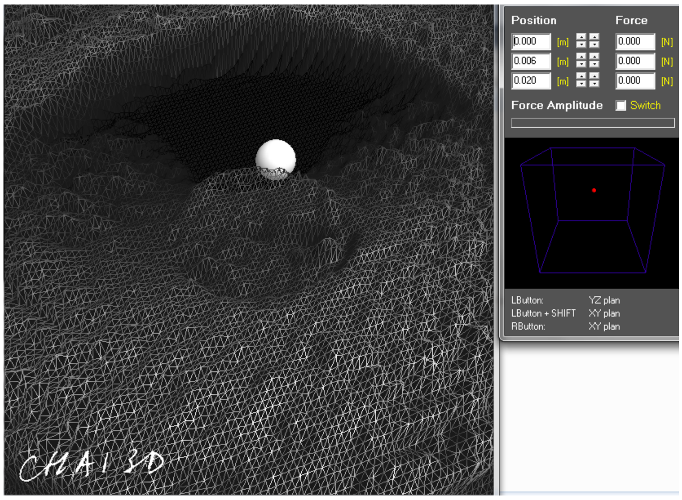

Fig 4 Haptics Visualization with real terrain media with a virtual haptics Device of Chai3D

VI. CONCLUSIONS

We have described here the interactive visualization system for terrain assessment, planning path for navigation of rover. The results of this study have shown that there is potential for haptics in interplanetary navigation and path planning over a terrain surface. Haptics used to feel the terrain of a surface is meaningful in generating the mental 3D model of terrain and make the best use of it in identifying the path over the surface by overcoming obstacles.

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